Interpreting Narrative Objectives for Biostimulatory Substances Using the Technical Approach for Developing California Nutrient Numeric Endpoints

Central Coast Ambient Monitoring Program Technical Report
California Central Coast Water Board
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Summary

The intent of this technical paper is to identify screening criteria for use in the 2008 303(d) / 305 (b) Integrated Report that will protect aquatic life beneficial uses from the consequences of excessive nutrient enrichment, or "biostimulation". In this paper, staff used data from the Central Coast Ambient Monitoring Program to establish an upper range for dissolved oxygen concentration, over which reference site oxygen concentrations rarely or never fell. Staff then examined the characteristics of data from sites that showed no evidence of biostimulation to identify a proposed screening criterion for nitrate of 1.0 mg/L-N to protect for aquatic life uses. Staff used the California Benthic Biomass Tool (Tetratech, 2007) to further evaluate these sites in terms of predicted oxygen deficit and determined that an oxygen deficit of 1.25 mg/L represents a low level of risk for biostimulation. Staff can support nitrate decisions in the Integrated report with additional evidence of biostimulation, including widely ranging dissolved oxygen concentrations, predicted oxygen deficit over 1.25, predicted benthic algal biomass and chlorophyll a concentrations over levels recommended by the California Nutrient Numeric Endpoint technical approach (Creager, 2006), filamentous algal cover over 50% and water column chlorophyll a concentrations over 15 mg/L.

Background

The Central Coast Basin Plan currently contains narrative language stating that "waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses." Excessive nutrient concentrations stimulate algal growth, which can create nuisance conditions for water use and recreation, but more importantly, can remove oxygen from water, creating conditions unsuitable for aquatic life. Some algal blooms are also toxic to aquatic life, wildlife, and even humans. Waters that contain excessive algal growth are characterized by wide swings in dissolved oxygen concentrations, typically dropping below concentrations set to protect for aquatic life at night, and often rising above fully saturated levels during mid-day.

Tetratech Inc. developed the California Nutrient Numeric Endpoint (NNE) technical approach (Creager, et al., 2006) for the State Water Resources Control Board in order to interpret the biostimulatory narrative objective, and to support

development of numeric criteria for nutrients to protect for aquatic life beneficial uses. The California NNE technical approach utilizes predicted benthic algae biomass and chlorophyll *a* concentrations as "response variables" to define Beneficial Use Risk Categories that can serve as preliminary numeric targets. These numeric targets are set at a conservative level to account for uncertainty and to be applicable throughout California. The NNE approach recommends 200 mg chlorophyll *a*/ square meter as the level above which risk of impairment by nutrients is probable in warm water streams, and 150 mg/m2 as the level at which risk is probable in cold water streams. It also sets 80 grams/m2 ash free dry weight (AFDW) for algal density in warm water streams and 60 grams/m2 AFDW for algal density in cold water streams.

The California NNE provides background support for use of the associated California Benthic Biomass Tool, v. 13 (Tetratech, February 2007), to predict in-stream benthic algal density and other metrics in response to a number of inputs. The Biomass Tool utilizes data inputs for nutrient concentrations, as well as for latitude, canopy cover, stream depth and velocity to generate several model outputs. These include benthic biomass and benthic chlorophyll *a* concentrations for both cold and warm water streams. It predicts these outputs for seven different models taken from the scientific literature. It also predicts the anticipated maximum oxygen deficit resulting from biostimulation. This is the maximum amount of dissolved oxygen expected to be removed from the water as a result of predicted algal growth. This latter value is calculated using the Benthic Tool EPA revised QUAL2K model.

The Water Quality Control Policy (WQCP) for developing California's Clean Water Act (CWA) Section 303(d) list (SWRCB, 2004) describes the process by which the State Water Board and Regional Water Boards will comply with the listing requirements of Section 303(d) of the federal CWA. Section 6.1.3 "Evaluation Guideline Selection Process" provides the requirements for a proposed guideline before it can be accepted for use as part of the 303(d) listing process. According to State Board staff analysis, the California NNE approach does meet these requirements, namely it is:

- Applicable to the beneficial use
- Protective of the beneficial use
- Linked to the pollutant under consideration
- Scientifically-based and peer reviewed
- Well described, and
- Identifies a range above which impacts occur and below which no or few impacts are predicted.

Central Coast Water Board staff has several goals in utilizing the California NNE technical approach to support assessment efforts for the 2008 Integrated Report. The current Basin Plan nitrate criterion is set to protect drinking water for human health purposes. For many years, Central Coast staff has worked with Tetratech

and staff from State Board and other Regions to support development of the California NNE approach, to provide us with a tool to protect against biostimulation. This approach is now in place, and we have used it here to support development of a nitrate criterion to protect for aquatic life. We have screened our highest priority water bodies for the 2008 listing cycle. It is our intent to further evaluate this approach over the next two years and to consider using it to develop Basin Plan objectives and to screen all water bodies for the 2010 Integrated Assessment.

CCAMP Reference Site Conditions

Oxygen Reference Range – Central Coast Water Board staff evaluated Central Coast Ambient Monitoring Program (CCAMP) diurnal oxygen data collected from 105 sites where probes were deployed for a 24-hour period during summer months. CCAMP collects this data to determine if oxygen levels drop during the highest risk time of day, which is pre-dawn. This is important because staff conducts routine monthly grab sampling between 9 a.m. and 4 p.m., when oxygen levels are typically highest.

From the diurnal data, staff established two sets of potential oxygen reference data. The first reference data set consisted of the 32 sites where dissolved oxygen concentrations never dropped below 7.0 mg/L, the cold water aquatic life standard. The second consisted of the 59 sites where dissolved oxygen concentrations never dropped below 5.0 mg/L, the warm water aquatic life standard. We examined oxygen concentrations of both diurnal and monthly grab sample data for these sites for each hour of the day (Figures 1 and 2). For the 32 cold water sites, 29 sites never exceeded 13 mg/L at any time. Of the 644 grab samples taken at these cold water oxygen reference sites, only 6 (or 1.0%) samples exceeded 13 mg/L. For the 59 warm water sites, 43 sites never exceeded 13 mg/L at any time. Of the 1695 grab samples taken at these warm water oxygen reference sites, only 32 (or 1.9%) samples exceeded 13 mg/L. Staff determined that 13 mg/L is an appropriate upper value to screen both warm and cold water sites for oxygen super-saturation outside of reference ranges.

Characteristics of Sites Showing No Evidence of Biostimulation – Staff evaluated CCAMP data for characteristics of sites meeting warm and cold water oxygen objectives that in staff's opinion do not show evidence of biostimulation. These sites fell within the oxygen reference ranges described above, and also had several other characteristics:

1) Water column chlorophyll *a* concentrations remaining under 15 ug/L. This value has been used for a number of years as a CCAMP screening value. The state of North Carolina has set a maximum chlorophyll *a* standard of 15 ug/L for cold water (lakes, reservoir, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters), and 40 ug/L for warm water (lakes, reservoir, and other waters subject to growths of macroscopic or

microscopic vegetation not designated as trout waters) and (North Carolina Administrative Code 15A NCAC 02B .0211 (3) (a)). Oregon uses an average chlorophyll *a* concentration of 15 ug/L as a criterion for nuisance phytoplankton growth in lakes and rivers (OAR, 2000). A chlorophyll *a* concentration of 8 ppb is recommended as a threshold of eutrophy for plankton in EPA's Nutrient Criteria Technical Guidance Manual for Rivers and Streams (2000).

2) Filamentous algal cover never exceeding 50% of the water's surface. Typical nuisance criteria cited in the literature for filamentous algal cover range from 40 to 55% (Stevenson, et al., 1996). The State of Nevada uses 50% cover as a screening threshold for filamentous algal cover to identify possible algae related problems (NDEP, 2007). Older CCAMP sampling methods did not distinguish between periphyton and filamentous algal cover, so this value could not be applied to older data. One site was removed from consideration because older data showed 100% "algal cover" on multiple occasions.

No sites from the cold water data set and only one site from the warm water data set had nitrate-N concentrations that exceeded 1.0 mg/L as an average (Figures 3 and 4). The single site that exceeded this value was located below a dam, and was well oxygenated as a result.

Application of the California Benthic Biomass Tool to CCAMP Data

Staff submitted CCAMP data (1998 – 2006) for water body minimums, maximums, and means for nitrate, nitrite, ammonia, ortho-phosphate, total phosphorus and water temperature into the California Benthic Biomass Tool. To screen data for probable effects, we utilized the recommended NNE warm water threshold values of 200 mg/m^2 for chlorophyll *a* and 80 grams/m^2 ash-free dry weight (AFDW) for algal density, and the cold water threshold values of 150 mg/m^2 for chlorophyll *a* and 60 grams/m^2 AFDW for algal density. We used a latitude of 35 degrees and a canopy cover of 80% as model inputs. Our assumption of a relatively dense canopy cover produces an estimate of probable effects that conservatively identifies problem conditions. We used default values in the Biomass Tool for several other model inputs, including stream velocity of 0.3 meters per second and stream depth of 0.5 meters. Resulting outputs provided estimates of biomass, chlorophyll *a* production based on input variables, and estimated oxygen deficit for each water body.

Predicted Oxygen Deficit – Staff evaluated resulting site outputs from the Biomass Tool for all CCAMP data. The Biomass Tool generated an estimated oxygen deficit for each site based on predicted algal biomass. Based on the nitrate concentrations associated with of CCAMP sites that do not show evidence of biostimulation, staff evaluated the oxygen deficit associated with sites that had average nitrate concentrations of 1 mg/L or lower. The maximum contribution of algae to oxygen deficit at this nitrate concentration was approximately 1.25 mg/L

(Figure 5). All of the cold water reference sites and most of the warm water sites fell within this level of predicted oxygen deficit (Figures 6 and 7).

Using Nitrate Screening Criterion to Develop Lines of Evidence

Nitrate and other nutrients are treated as "toxins" by the Listing Policy (SWRCB, 2004). Consequently, in developing Lines of Evidence for the 2008 Integrated Report, staff evaluated nitrate potential for biostimulation using the binomial distribution established for toxic pollutants in Table 3.1 of the Listing Policy, based on exceedance of 1.0 mg/L nitrate (as N). Staff provided further evidence of biostimulation using supporting data and Biomass Tool model outputs. These included predictions of benthic algal biomass and/or benthic chlorophyll *a* concentrations exceeding model thresholds for warm and cold water habitat, evaluation of model prediction of oxygen deficit relative to the 1.25 mg/L threshold established by staff, and evaluation of data for evidence of oxygen depression and/or super-saturation, which are both indications of biostimulation. Staff will further evaluate these nitrate and oxygen deficit values over the next two years for consideration in a Basin Plan amendment related to biostimulation, and for future listing evaluations.

References

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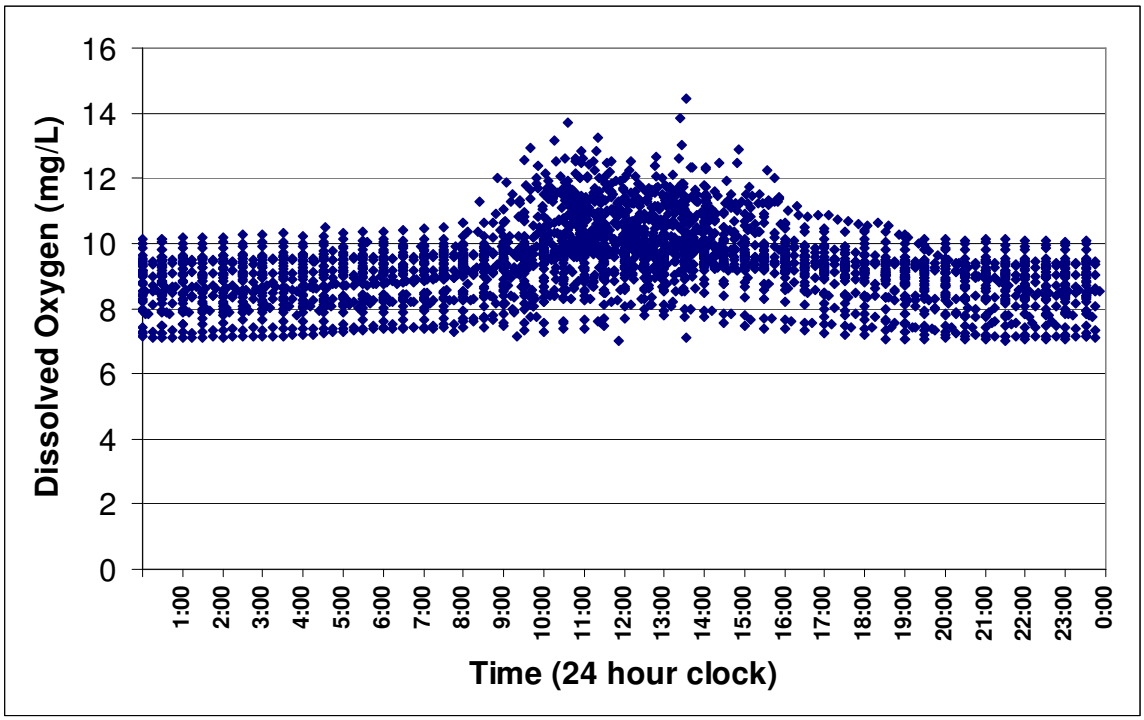

Figure 1. Hourly dissolved oxygen at cold water reference sites (CCAMP data, 1998 – 2008). Includes 24-hour probe and grab sample data.

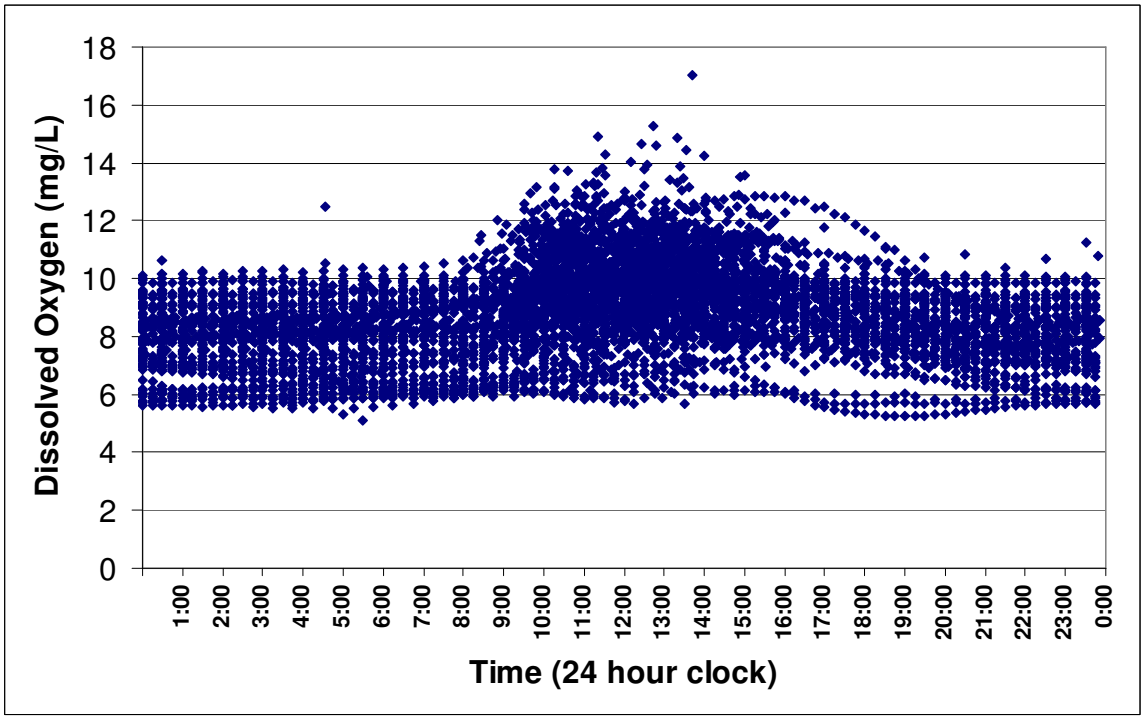

Figure 2. Hourly dissolved oxygen at warm water reference sites (CCAMP data, 1998 – 2008). Includes 24-hour probe and grab sample data.

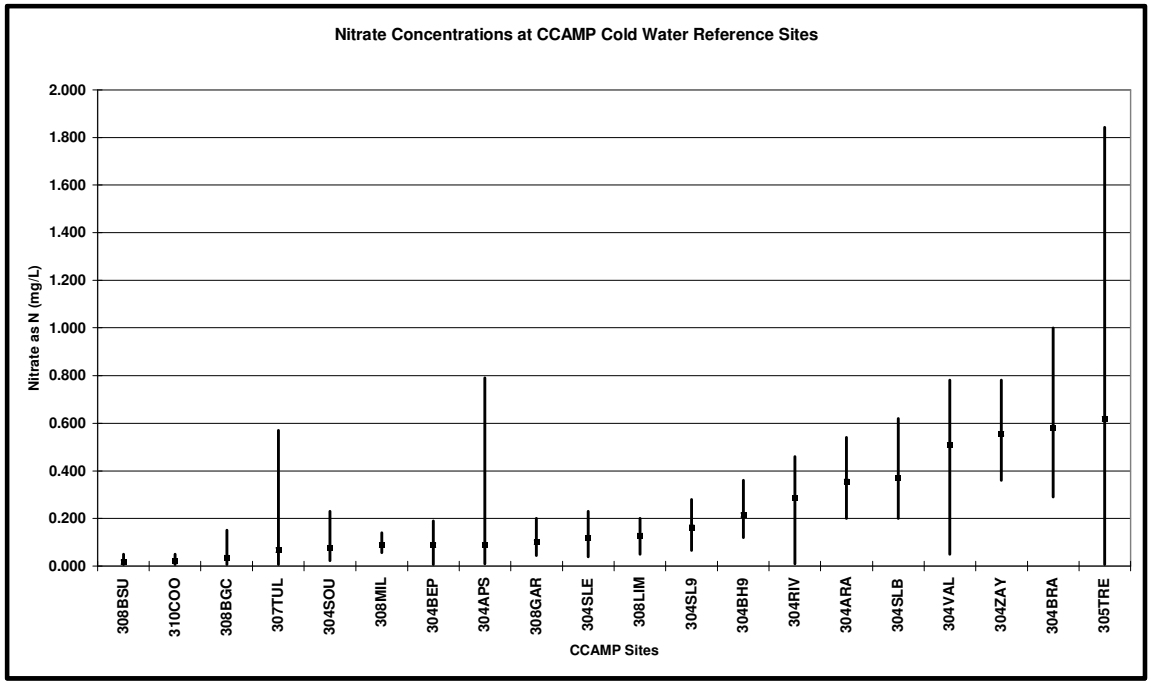

Figure 3. Mean Nitrate concentrations (mg/L) at CCAMP sites that never violate the Cold Water Oxygen Objective (7 mg/L) and that do not exceed several screening criteria for indicators of biostimulation.

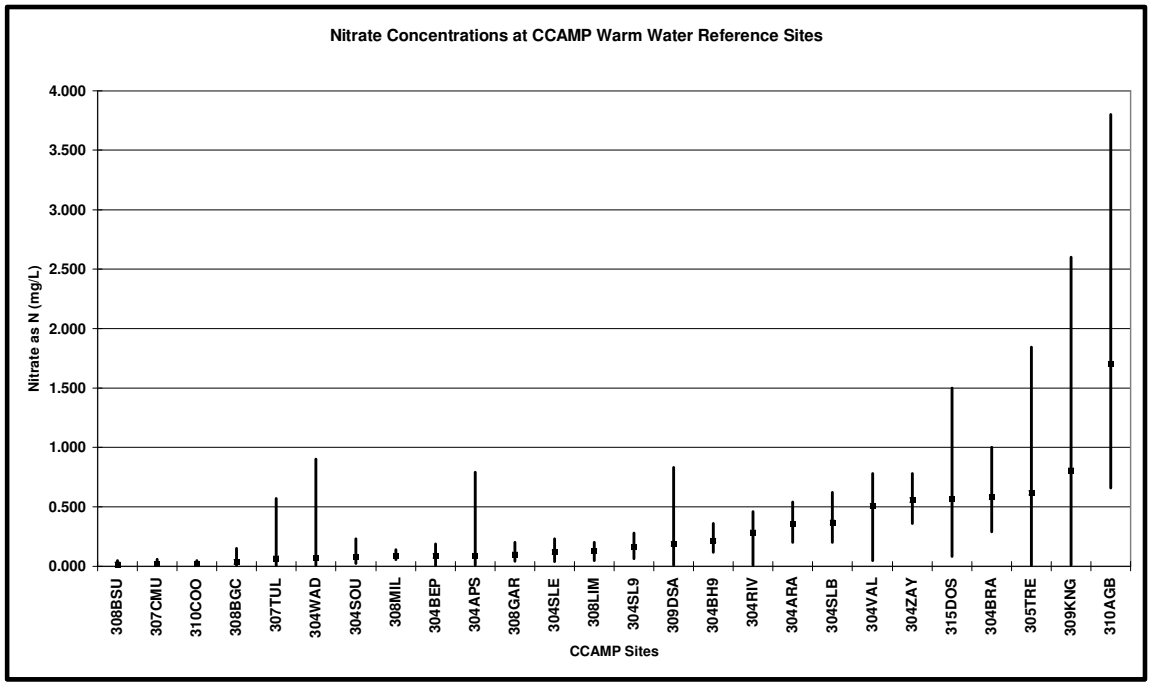

Figure 4. Mean Nitrate (as N) concentrations (mg/L) at CCAMP sites that never violate the Warm Water Oxygen Objective (5 mg/L) and that do not exceed several screening criteria for indicators of biostimulation.

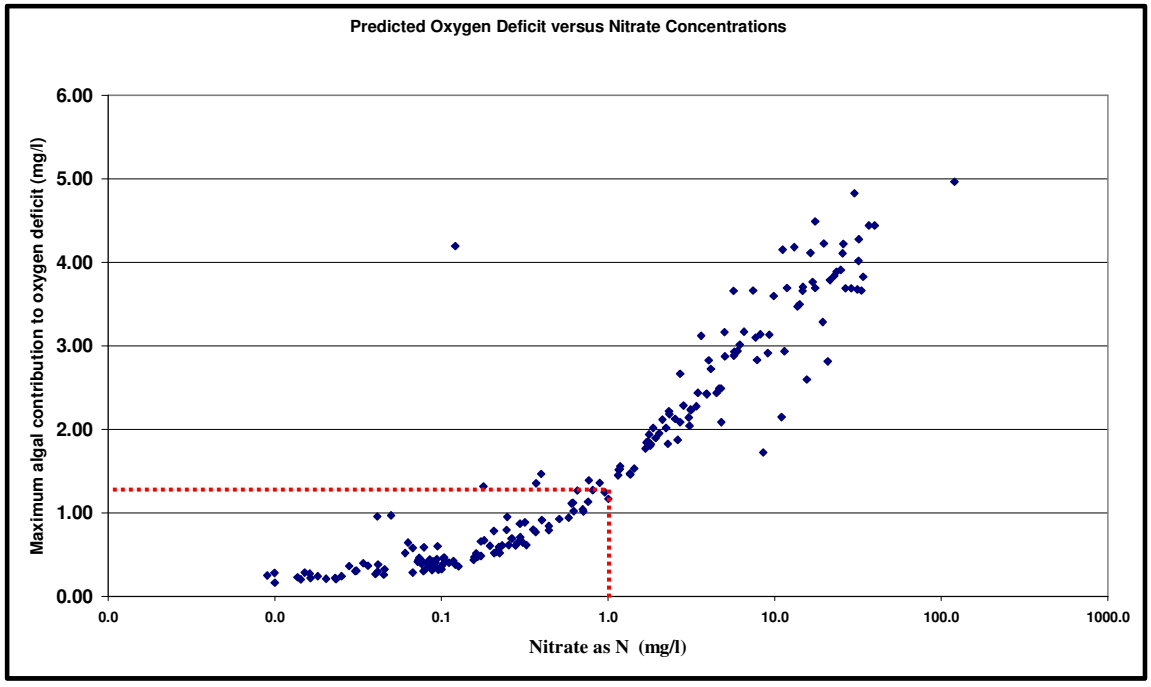

Figure 5. Relationship between average site nitrate concentrations (as N) and predicted oxygen deficit (mg/L). An average nitrate concentration of 1.0 mg/L predicts an estimated maximum algal contribution to oxygen deficit of approximately 1.25 mg/L, based on the California Benthic Biomass Tool (2007).

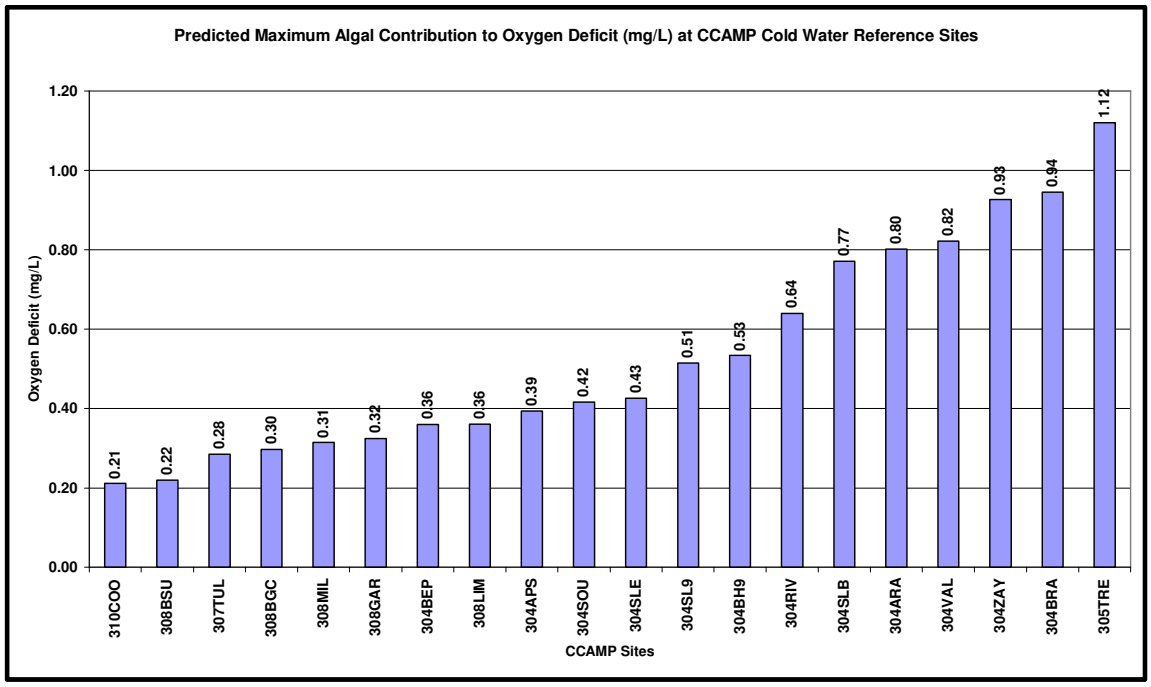

Figure 6. Predicted Maximum Algal Contribution to Oxygen Deficit (mg/L) for CCAMP sites that never violate the Cold Water Oxygen Objective (7 mg/L) and that do not exceed other screening criteria for indicators of biostimulation.

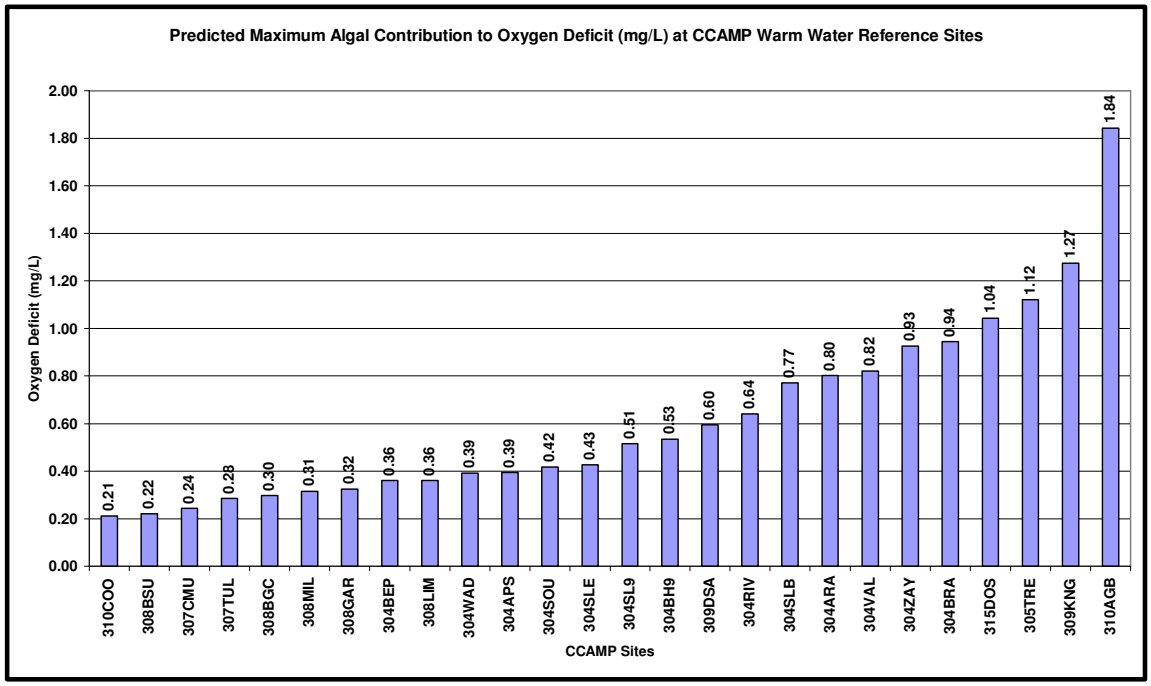

Figure 7. Predicted Maximum Algal Contribution to Oxygen Deficit (mg/L) for CCAMP sites that never violate the Warm Water Oxygen Objective (5 mg/L) and that do not exceed other screening criteria for indicators of biostimulation.